BSC

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YUCCA MOUNTAIN PROJECT

WASTE PACKAGE TRANSPORT AND EMPLACEMENT VEHICLE DESIGN DEVELOPMENT PLAN

(Study Title)

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DISCLAIMER

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TABLES

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ACRONYMS

BSC	Bechtel SAIC Company, LLC
BOD	Basis of Design (Document)
DDP	design development plan
DOE	U. S. Department of Energy
FMEA	failure mode and effects analysis
FTA	fault tree analysis
ITS	important to safety
NSDB	Nuclear Safety Design Basis
P&ID	Process and Instrumentation Diagram
SSCs	structures, systems, and components
TAD	transportation, aging, and disposal
TEV	transport and emplacement vehicle
WP	waste package

1. PURPOSE

This design development plan (DDP) identifies the process for advancing the design of the transport and emplacement vehicle (TEV) to meet its credited safety functions. This DDP will identify the means of demonstrating that the TEV can be relied upon to perform its nuclear safety design bases (NSDBs) identified in the *Basis of Design for the TAD Canister–Based Repository Design Concept (BOD)*, (Reference 12.1.1). Furthermore, this DDP will define the planned approach of design development activities and provides the basis for the subsequent development of performance specifications, test specifications and test procedures.

2. SCOPE

The scope and extent of this DDP are driven by development requirements defined within the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study*, (Reference 12.1.3). Although TEV structure, system, and component (SSC) designs are based on proven and commercially available technology, this design development plan identifies areas where performance acceptance cannot be readily achieved through the use of consensus codes and standards and in conjunction with a recognized equipment qualification program.

The scope of this DDP is limited to identifying the planned approach and design development activities necessary to advance the design of the TEV to demonstrate that it meet its credited NSDBs. Thereafter, this DDP will form the basis for defining design development and testing requirements within the TEV performance specification. The performance specification will define the codes, standards, and performance requirements for design, fabrication, and testing of the equipment. Testing activities will be detailed in test specifications and test procedures. Test specifications will detail the requirements for each test, and testing procedures will prescribe how each test is to be performed.

This DDP was prepared by the Subsurface / Mechanical team and is intended for the sole use of the Engineering department in work regarding the TEV. Yucca Mountain Project personnel from the Emplacement and Retrieval project team should be consulted before using this DDP for purposes other than those stated herein or for use by individuals other than those authorized by the Engineering department.

3. PROGRESSIVE APPROACH

Design development requirements and activities identified in this DDP are commensurate with the level of design completed for the License Application and the associated gap analysis study. However, specific design details and the selection of specific SSCs may not be known, and all design development requirements may not have been identified in the gap analysis study.

Therefore, a progressive design development approach is presented in this DDP that provides a framework for identifying and detailing design development requirements and activities as the design advances. It is anticipated that as the design matures, to the extent practicable, SSCs that perform important to safety (ITS) functions will be selected based on proven technology and codes and standards that provide assurance they will perform as required without need for extensive design development.

The progressive design development approach includes, as appropriate, the design development activities identified in Section 8. Completion of each design development activity and advancement of the design will determine the need for further design development and completion of additional design development activities.

In addition, the progressive design approach maintains flexibility throughout the design process to allow alternative solutions to be explored without compromising design development objectives.

4. DESIGN DEVELOPMENT OBJECTIVES

The primary objectives of this DDP are to demonstrate the reliability of TEV performance against:

- TEV runaway (Reference 12.1.1, Section 14.2.3.1.1)
- TEV tipover due to seismic events (Reference 12.1.1, Section 14.2.3.1.1)
- Derailment due to seismic (Reference 12.1.1, Section 14.2.3.1.1).
- WP ejection from the TEV (Reference 12.1.1, Section 14.2.3.1.1).
- Inadvertent TEV door opening (Reference 12.1.1, Section 14.2.3.1.1).

5. QUALITY ASSURANCE

This informal study was prepared in accordance with EG-PRO-3DP-G04B-00016, *Engineering Studies* (Reference 12.1.4). The results presented are only to be used as the basis for selecting design development activities and are not to be used directly to generate quality-affecting products. Therefore, this DDP is not subject to requirements of the *Quality Management Directive* (Reference 12.1.2) document.

6. FUNCTIONAL DESCRIPTION

The function of the WP transport and emplacement vehicle (TEV) is to transfer a WP and its associated emplacement pallet from the WP loadout room within any surface facility, through the North Portal, down the Access Main, and onto the final emplacement position within the emplacement drift. The TEV can be used for waste package and pallet retrieval. The retrieval process is a reversal of the emplacement procedure.

The TEV is designed to be radiologically shielded, electrically powered, self-propelled, rail-based, and remotely controlled. It will run on standard crane rails and is capable of operating within the Subsurface, Canister Receipt and Closure Facilities (CRCF) 1, 2, and 3, Initial Handling Facility (IHF) and the Heavy Equipment Maintenance Facility (HEMF).

To perform its tasks the TEV has two basic functions. It must be able to lift or lower a WP and pallet and it must be able to carry the WP and pallet from a surface facility to an emplacement drift, or vice versa.

7. NON-STANDARD STRUCTURES, SYSTEMS, AND COMPONENTS

Non-standard SSCs are defined as; SSCs not based on commercially available equipment, established industry practices, or consensus codes and standards. The approach for the TEV design is to use standard components and SSCs where possible.

The *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3) identified SSCs that perform ITS functions and the applicable codes and standards. The work done in the Gap Analysis will provide assurance the ITS SSCs will perform as required. In all cases, the ITS functions and requirements can be met using standard SSCs and codes and standards that have been developed and used in nuclear applications. The *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3) did not identify any non-standard SSCs that require design development. However, there may be non-ITS design development needs. Non-ITS design development needs are discussed in generic terms only. The specification will dictate what level of non-ITS development needs are required.

8. DESIGN DEVELOPMENT ACTIVITIES

The following design development activities represent the progressive design-development approach used to advance the TEV design. In turn, as the design advances, the need to complete each design development activity (or selectively complete activities) should be determined based on meeting each credited safety function. Design development activities are described in Section 9.

- Design Activities:
  - Selection of SSCs
  - Engineering calculations
  - Computer modeling
  - Failure modes and effect analysis (FMEA)
  - Fault tree analysis (FTA)

Specific design development activities identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3) are summarized in Appendix A: ITS SSC Design Development Needs.

Proven nuclear technologies and adaptations of similar designs will be used to the extent practicable. The TEV component failure rates will be established based on similar components used in industry. The functionality of the TEV control, communication, and electrification system will also be based on similar components used in industry.

9. DESIGN DEVELOPMENT DESCRIPTIONS

9.1 SELECTION OF STRUCTURES, SYSTEMS, AND COMPONENTS

To the extent practicable, SSCs should be selected based on proven technologies that have been used in similar environmental and nuclear operating conditions. Selection of SSCs with proven nuclear pedigrees and well-documented histories may reduce the need for subsequent design development. SSCs certified to IEEE Std 323-2003, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*, (Reference 12.2.2) may require little or no physical design development activities. In contrast, the selection of new technologies could require testing to confirm the adequacy of the equipment design under normal, abnormal, design basis event, and post-design basis event conditions, as well as the suitability of the materials and methods of construction.

9.2 ENGINEERING CALCULATIONS

As the design progresses and solutions are evaluated, especially for structural components and stability, engineering calculations could include (at a minimum) the TEV structure and the pallet lifting fabrications. Calculations will be required, to confirm that acceptable stress and strain levels are maintained and maximum deflections are not exceeded. Additional calculations will be required to confirm the stability of the TEV in preventing tip over, as was identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3).

9.3 COMPUTER MODELING

Computerized, three-dimensional modeling should be conducted for design verification during the advancement of the TEV detail design to ensure that the TEV will perform within the bounding envelope of the emplacement drift. Three-dimensional modeling may also be applied to the TEV lifting system to verify performance acceptance as alternative design options are considered. Finite element modeling may be used during design development to provide evidence that design stress levels are not exceeded, especially for the TEV structure, the lifting hook fabrications, and the lifting system components as an assembly. This modeling is considered studied engineering practice and is not tied to an ITS requirement and will therefore not be identified as an ITS design development activity.

9.4 FAILURE MODE AND EFFECTS ANALYSIS

FMEA should be performed on the TEV using ANSI/IEEE Std 352-1987, *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems* (Reference 12.2.1). Alternately reliability analyses performed by the Preclosure Safety Analysis group or approved by that group (if performed by the supplier) may be used for demonstrating the reliability requirements of the NSDB.

The FMEA is usually the first reliability activity performed to provide a better understanding of the failure potential of a design. The FMEA may be limited to a qualitative assessment, but may include numerical failure probability estimates. Important applications of the FMEA include:

- Specifying future tests required to establish whether design margins are adequate relative to specific failure mechanisms identified in the FMEA
- Identifying "safe" and "unsafe" failures for use in the quantitative evaluation of safety-related reliability
- Identifying critical failures that may dictate the frequency of operational tests and maintenance intervals if the failure modes cannot be eliminated from the design
- Establishing the quality-level for parts needed to meet reliability goals
- Identifying unacceptable failure mechanisms (failures that could produce unacceptable safety or operational conditions) and the need for design modifications to eliminate them
- Identifying the need for failure detection.

FMEA should be used to identify, by component, all known failure modes, failure mechanisms, effects on the system, the method of failure detection, and provisions in the design to compensate for the failures. The analysis should provide established reliability statistics based on failure rates for components used in similar applications and environmental conditions. Reliability data, where available, will be obtained from nuclear facilities with similar quality control requirements. This activity is a prerequisite to performing a detailed fault tree analysis, and it provides the first level of design validation during the conceptual design phase. The FMEA should be periodically updated to reflect changes in design as the design matures.

9.5 FAULT TREE ANALYSIS

FTA should be performed on the TEV using ANSI/IEEE Std 352-1987(*IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems)* (Reference 12.2.1). Alternately reliability analyses performed by the Preclosure Safety Analysis group or approved by that group (if performed by the supplier) may be used for demonstrating the reliability requirements of the NSDB.

Fault tree analysis should be used to determine the causes and probability of the safety requirements stated in *Basis of Design for the TAD Canister–Based Repository Design Concept* (Reference 12.1.1). The fault tree analysis, performed in conjunction with the results of the FMEA, should provide adequate design validation to proceed with final design. Important benefits of FTA include:

- Identifying possible system reliability and safety problems during the design phase
- Assessing system reliability and safety during operation
- Improving the understanding of component interaction within a system

- Identifying components that may need testing or more rigorous quality assurance scrutiny

- Identifying root causes of equipment failures.

9.6 BENCH TESTING OF COMPONENTS

Components that do not have a proven history of operating in radiological environments similar to those expected at Yucca Mountain could be subject to bench testing. For the bench test a facility capable of handling radiation sources and bounding environmental conditions would be required.

Currently there are no required bench testing activities anticipated for TEV ITS SSCs.

9.7 EXTENDED FACTORY ACCEPTANCE TESTING

The *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3) did not identify any specific Extended Factory Acceptance testing required for the TEV ITS SSCs. Extended Factory Acceptance testing will be in accordance with the codes and standards identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3) as well as the factory acceptance testing section of the design specification.

The basic approach for extended factory acceptance testing is to test the critical systems in an environment that simulates the actual operating environment as closely as possible. Extended factory acceptance testing would be performed at full-scale because some components are unavailable at a reduced scale. Full-scale testing would be recommended for the following reasons:

- Results from a scale model may not be as accurate.

- Components from a scale model can not be reused.

- Scale components my not be available in all cases.

Extended factory acceptance testing is performed in the following three phases:

- Phase I: Accelerated testing

- Phase II: Extended testing

- Phase III: Sustained testing.

9.7.1 Accelerated Testing

There are no additional ITS SSC accelerated testing requirements identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3). Testing will be in accordance with the codes and standards identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3).

Accelerated testing would simulate the full life-cycle operations of the TEV for all moving parts (e.g., motors, gearboxes, shafts, brakes, and screw jacks) in a compressed time period. This activity could also include full life-cycle control sequence testing of the control system, including the programmable logic controller, all control instrumentation, switches, sensors, and cabling. The control and instrumentation cabinets could be full life-cycle tested relative to the environmental resistance capabilities under representative operating conditions

Life-cycle operations should be based on all normal movements and conditions associated with emplacing an assumed three (3) WPs per day during a 365-day period per year. Additionally Life-cycle operations would be based on an operating shift of eight hours per day, with three operating shifts per day. Each operating shift yielding one emplaced WP.

9.7.2 Extended Testing

There are no additional ITS SSC extended testing requirements identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3). Testing will be in accordance with the codes and standards identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3) as well as the factory acceptance testing section of the design specification.

Extended testing could simulate extended life-cycle operations for all moving parts (e.g., motors, gearboxes, shafts, brakes, and screw jacks) of the TEV. This activity would also include full life-cycle control sequence testing of the control system, including the programmable logic controller, all control instrumentation, switches, sensors, and cabling. The control and instrumentation cabinets could also be full life-cycle tested relative to environmental resistance capabilities under representative operating conditions.

9.7.3 Sustained Testing

There are no additional ITS SSC sustained testing requirements identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3). Testing will be in accordance with the codes and standards identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3) as well as the factory acceptance testing section of the design specification.

Sustained testing could simulate TEV components performance under off-normal environmental and operational conditions. Off-normal conditions include, for example, high and low temperatures, over travel, collisions, offset loads, loss of power, communication failure, and seizure of moving parts. Details that would be considered during sustained testing, and the components to test include:

- All load path and linear travel components, testing at a minimum, moving parts seizure.
- All components of the lifting and linear travel control systems, testing could concentrate on, but not be limited to, loss of power, communication, and spurious signals.

- Testing could determine that over-travel of the linear drive system associated with an off-normal event should be prevented by the control system, the braking system, the end-of-travel rail stops at the end of the emplacement drift, or a combination of these.

- Testing could determine that over-travel of the linear drive system during WP emplacement within the required tolerances should be prevented by the control and braking system.

- Consideration could also be given to the electronic positional control system coupled with the visual capabilities provided by the on-board cameras and communication system.

9.8 OFF-SITE INTEGRATED TESTING

There are no additional ITS SSC Offsite Integrated testing requirements identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3). Testing will be in accordance with the codes and standards identified in the *Waste Package Transport and Emplacement Vehicle Gap Analysis Study* (Reference 12.1.3) as well as the factory acceptance testing section of the design specification.

Off-site integrated testing could be performed to demonstrate interfaces with various waste packages and pallets, and the subsurface facility. Off-Site integrated testing would be fully representative, to the extent practicable, of real operations with the exception of a radioactive environment.

Off-Site integrated testing would be recommended for the following reasons:

- Demonstrate functionality of the complete system under simulated operational conditions

- Demonstrate the practicality of recovery and retrieval plans

- Verify the system performance prior to delivery to site (including rail curves and grades)

- Provide preparation for operational readiness review

- Permit hands-on involvement of regulatory agencies

- Provide feedback for necessary modifications or design enhancements.

9.9 OPERATIONAL READINESS REVIEW

Although the operational readiness review is beyond the scope of this DDP, it is mentioned here for completeness. An operational readiness review would follow off-site integrated testing and highlights the final milestone in demonstrating the performance of production ITS SSCs.

10. INFORMATION COLLECTION AND INSPECTION REQUIREMENTS

The primary objective of this DDP is to demonstrate the reliability of ITS TEV functions under representative operational conditions. Although, individual components will be selected based on previous use in similar nuclear applications, it is unlikely that they have been used within the same configuration or for exactly the same application and therefore component failure or excessive wear may be influenced by unknown interactions. Therefore, to evaluate component failures that influence reliability, it is essential that information be collected during each stage of the component life (i.e., manufacture, construction and operation). This information may then be used to ensure that a root cause analysis can be performed on the components that do not meet design and performance objectives.

10.1 BASELINE DATA

To assess wear and failure modes of ITS components, it is essential that detailed baseline data be obtained. The data, at a minimum, should include a physical inspection of each component before and after installation to identify defects and anomalies. All noted defects and anomalies must be addressed prior to testing. Typical data should include weights, important dimensions, and surface finishes.

10.2 ACCELERATED TEST DATA

Throughout life-cycle factory acceptance testing, sufficient instrumentation should be provided to monitor the performance of ITS components. Instrumentation should provide real-time monitoring and feedback on important measurements and operating parameters. Measurements could include.

- The effects of temperature on components and fabrications caused by environmental temperatures coupled with the heat developed by components during operation (e.g., screw jacks, motors, gearboxes, bearings, speed control equipment, sensors, switches, cables, and relays).
- The ventilation system for the control cabinets should be monitored to ensure acceptable temperatures for the electronic components (e.g., switches, relays, and cables).
- The effects of the design loads on all load bearing components and fabrications could be monitored for stress and strain levels, physical deflections, and reductions in surface finish on load-path components (e.g., shafts, bearings, and screw jacks) caused by wear.
- Motor power requirements could be recorded during the operations of linear movement, lifting, and lowering.
- The linear drive and load path components (e.g., motors, gearboxes, bearings, and screw jacks) could be monitored for vibration and sound during operating cycles.
- The control systems for linear travel and lifting could be monitored under all conditions.

During accelerated testing, components would be inspected and maintained (e.g., adjustments and lubrication) as part of a scheduled maintenance regime based on vendor data. Where practicable, supplement vendor data with predictive maintenance and condition-monitoring techniques.

10.3 EXTENDED TEST DATA

Data requirements for extended testing are similar to those for accelerated testing, with the exception that a detailed inspection of each ITS component needs to be performed prior to testing to determine component wear and life expectancy.

10.4 SUSTAINED TEST DATA

Data requirements for sustained testing are similar to those for accelerated testing, with the exception that a detailed inspection of each ITS component needs to be performed after each sustained test evolution to monitor for evidence of progressive fatigue, cumulative fatigue, and component failure.

10.5 OFF-SITE INTEGRATED TEST DATA

After extended, bench, and factory acceptance testing of individual components is complete, it will be necessary to demonstrate the overall functionality of the complete system. This phase of testing is referred to as integrated testing. To the extent practicable, integrated testing will be used to demonstrate the performance of the complete system under simulated operating conditions. Prior to off-site integrated testing, used equipment should be refurbished or replaced to new condition. Data collection for integrated testing should be fully representative of anticipated operating conditions (excluding radiation environment).

11. EXPECTED RESULTS AND SUCCESS CRITERIA

The expected results and success criteria, based on satisfying the ITS performance requirements specified in *Basis of Design for the TAD Canister–Based Repository Design Concept (BOD)*, (Reference 12.1.1), are outlined in this section. Deviations from expectations should be subjected to close inspection or further evaluation. If necessary, additional testing may be required to verify the data or to provide additional information for root cause analyses.

11.1 ACCELERATED TESTING

ITS reliability requirements specified in *Basis of Design for the TAD Canister–Based Repository Design Concept (BOD)*, (Reference 12.1.1) must be met, as specified in Table 11-1.

To achieve the reliability requirements, it is expected that the TEV will not require any unplanned maintenance. Where practicable, components should be selected or designed to support an operational life without breakdown or the need for replacement. Failure of ITS components within this period, results that are not consistent with vendor data, and bench testing should be closely evaluated to determine root causes for any failures or problems found.

Table 11-1: Reliability Requirements

NSDB Requirements	Target Reliability
TEV runaway	5×10^{-9} per WP trip
TEV tipover due to seismic events	1.2×10^{-6} per year
Derailment due to seismic	9.9×10^{-5} per year
WP ejection from the TEV	2.3×10^{-4} per year
TEV Inadvertent door opening	1×10^{-7} per WP trip

Source: Reference 12.1.3, Section 4.

11.2 EXTENDED TESTING

Extended testing would provide added confidence that ITS reliability requirements can be meet with a degree or margin over an extended operational life. Therefore, successful extended testing should conclude with results that further support accelerated testing. Extended testing could provide a basis for the timing of planned maintenance outages during which components and assemblies would be inspected and maintained.

11.3 SUSTAINED TESTING

Sustained testing could provide added confidence that ITS reliability requirements can be meet with a degree or margin under off-normal conditions. Therefore, successful sustained testing would conclude with results that further support accelerated and extended testing. Sustained testing would highlight potentially weak areas, demonstrate areas of unacceptable wear, and identify signs of fatigue. This testing could add confidence to the frequency of planned maintenance outages.

11.4 OFF-SITE INTEGRATED TESTING

Off-site integrated testing would provide assurance the system will perform all required safety functions and that interactions with other equipment interfaces including recovery systems are as specified. During this testing, improvements may be highlighted that will be incorporated prior to delivery and installation of the equipment on site.

12. REFERENCES

12.1 DOCUMENTS CITED

12.1.1 *Basis of Design for the TAD Canister-Based Repository Design Concept*

BSC (Bechtel SAIC Company) 2007. *Basis of Design for the TAD Canister-Based Repository Design Concept.* 000-3DR-MGR0-00300-000-002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080229.0007

Project Design Criteria Document

BSC 2007. *Project Design Criteria Document.* 000-3DR-MGR0-00100-000-007. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071016.0005.

12.1.2 *Quality Management Directive*

BSC 2007. *Quality Management Directive.* QA-DIR-10, Rev. 1. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20070330.0001.

12.1.3 *Waste Package Transport and Emplacement Vehicle Gap Analysis Study*

BSC 2007. *Waste Package Transport and Emplacement Vehicle Gap Analysis Study*. 800-30R-HE00-01300-000-003. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080306.0006

12.1.4 *Engineering Studies*

EG-PRO-3DP-G04B-00016, Rev. 4. *Engineering Studies*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070406.0004.

12.2 CODES AND STANDARDS

12.2.1 ANSI/IEEE Std 352-1987

ANSI/IEEE Std 352-1987. *IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems.* New York, New York: The Institute of Electrical and Electronics Engineers. TIC: 246332.

12.2.2 IEEE Std 323-2003

IEEE Std 323-2003. 2004. *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.* New York, New York: Institute of Electrical and Electronics Engineers. TIC: 255697.

APPENDIX A. ITS SSC DESIGN DEVELOPMENT NEEDS

Appendix A: ITS SSC DESIGN DEVELOPMENT NEEDS

Table A-1. Design Development Activities for ITS SSCs

Nuclear Safety Design Basis Requirement	Applicable SSCs	ITS Design Development Needs[1]			
		Required Analysis	**Required Drawings**	**Required Modeling**	**Required Testing**
The mean probability of runaway of a TEV that can result in a potential breach of a waste package shall be less then or equal to 2.0 x 10^{-09} per transport. (Reference 12.1.1, Section 14.2.3.1.1).	Drive Motors, Gearboxes, Driveshafts, Wheels	Reliability Analyses	Detail Design Assembly Drawings	None Indicated in the GAP Analysis	None Indicated in the GAP Analysis
The mean frequency of tipover of the TEV due to the spectrum of seismic events shall be less than or equal to 2.0 x 10^{-06} /yr.(Reference 12.1.1, Section 14.2.3.1.1).	Center of Gravity / Stability	Reliability Analyses Tipover Calculation	Detail Design Assembly Drawings	None Indicated in the GAP Analysis	None Indicated in the GAP Analysis
The mean frequency of derailment of the TEV at the loadout station due to the spectrum of seismic events shall be less than or equal to 1.0 x 10^{-04} /yr. (Reference 12.1.1, Section 14.2.3.1.1).	Seismic Restraints	Reliability Analyses	Detail Design Assembly Drawings	None Indicated in the GAP Analysis	None Indicated in the GAP Analysis
The mean frequency of ejection of a waste package from the TEV due to the spectrum of seismic events shall be less than or equal to 2.0 x 10^{-04} /yr. (Reference 12.1.1, Section 14.2.3.1.1).	Front Shield Door Locks Front Shield Doors Front Shield Door Hinges	Reliability Analyses Door Impact calculation	Detail Design Assembly Drawings	None Indicated in the GAP Analysis	None Indicated in the GAP Analysis
The mean probability of inadvertent TEV door opening shall be less than or equal to 1.0 x 10^{-07} per transport.	Rear Shield Door Actuators, Front Shield Door Locks, Circuitry for hardwired interlock, Interlock switch	Reliability Analyses	Detail Design Assembly and Wiring Drawings, P&IDs and Logic Drawings	None Indicated in the GAP Analysis	None Indicated in the GAP Analysis

Note 1: This table identifies the design development activities required for ITS components, not what is required for the entire design process.